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STATE DOCUMENTS

*MONTANA FACT FINDING COMMITTEE  
ON  
HIGHWAYS, STREETS AND BRIDGES*



*INCREMENTAL*

*METHOD*

*OF DETERMINING*

*MOTOR VEHICLE TAX RESPONSIBILITY*

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## The Reason.

One of the main problems faced by any legislature is the equitable allotment of taxes amongst the recipients of benefits provided by the government. In the matter of distributing the costs of highway construction and maintenance, this problem is most difficult to solve because of the complex use of the facilities. Motor-vehicle users not only employ the highways for different purposes, but also impose different conditions upon its structure, requiring the improvement of standards in some cases, and contributing to the decline of existing facilities in others. Because of the complexity of the problem, the road tax structures in most States, while based on reasonable presumption and experience, fall far short of the desired goal of equity.

In recent years, highway tax studies throughout the States have sought to establish a firm basis, or measuring stick, for a reasonable and fair apportionment of highway costs amongst the users of highways. Different methods of analysis have been applied. The most common is probably the gross ton mile method, which would assign relative responsibility between motor vehicle groups according to the product of gross weight transported by vehicle miles travelled. This has the appearance of an equitable solution, since it takes into consideration the two major factors known to influence road costs; weight and relative use. However, the gross-ton mile theory fails to account for the actual relationship between weight and road costs and, in fact, is predicated on the assumption that such a weight cost relationship cannot be accurately determined. It, therefore, disregards known factors, and ignores the road in the assignment of tax responsibility. Another method of analysis which has been applied is the cost function method. This approach to the problem groups the different elements of construction and maintenance cost, according to the benefits provided to different classes of highway-user. Thus, there are "standby" costs which are apportioned to all vehicles equally; "non-weight-use" costs which are apportioned by relative use or vehicles miles; and "weight-use" costs which are apportioned to heavy vehicles by ton-miles. This is certainly a scientific approach to the problem. However, each detail of road construction does not easily fit a category where its benefits to one or another class of vehicle are clearcut. Considerable argument must result from application of the method. Other methods of analysis are likewise complicated, and often ignore the effect of the vehicle on the roadway.

Of all the methods applied, one stands out as both scientific and reasonable. This involves the engineering or incremental approach, and is sometimes called the method of differential costs. The following general description of the incremental method is taken from a memorandum to members of the Committee on Highway Taxation and Finance, Sub-committee No. 1B, of the Highway Research Board, dated December 1952.

"The salient characteristic of the incremental method, sometimes known as the method of differential costs, is that it purports to assign motor vehicle tax responsibility in proportion to the highway costs occasioned by





vehicles of different types and sizes. The use of the term "incremental" arises from the fact that most highway costs that are variable with size of vehicles may be considered as built up from a basic cost in which all vehicles share, and to which successive increments are added to accommodate the requirements of vehicles in ascending order of size."

For example: A flexible pavement structure composed of two inches of plant-mix asphalt, four inches of crushed rock cushion, and twelve inches of select, compacted sub-base material, would easily support considerable traffic of loaded two-axle vehicles weighing five tons. State practice may determine that three inches of plant-mix asphalt with the same supporting structure is necessary to accommodate the same traffic of eight ton two-axle vehicles. In making an incremental assignment, the first truck would only pay its share of the cost of the two-inch mat, since the additional thickness required for the larger vehicle is of no benefit to it. The second vehicle would pay its share of the two-inch mat, plus an additional share of the three-inch mat. Vehicles still larger would be assigned shares of the first two "increments" plus share of any additional thickness required for their accommodation.

Mr. D. F. Pancoast, in a report titled, "Allocation of Highway Costs in Ohio by the Incremental Method," makes the following pertinent remark: "It is important to note that the incremental method is used only for allocating the motor-vehicle share of highway costs. What that share should be, as compared to the share to be borne by abutting property, the general government, or other beneficiaries of highways, must first be determined by other means."

#### The Method

The incremental solution to the problem of allocating responsibility to motor-vehicle users for the cost of highway facilities is still in the development stage throughout the United States. Although certain concepts have been fairly well established, there is a wide range of possibilities in applying these concepts. Certain problems peculiar to each State warrant individual analysis. The purpose of this report is to describe the basis of a scheme of distribution of incremental costs which will relate to practical highway building in Montana. In order to compare this proposition with the most recent developments in application of the incremental method, a general description of studies performed by other States and agencies follows:

The most advanced thinking to date on the problems involved in making an incremental analysis is presented in a series of memoranda to members of the Committee on Highway Taxation and Finance of the Highway Research Board. Since the Fall of 1951, this Committee has been engaged in developing a framework for the incremental solution. Mr. D. F. Pancoast, a contributing member to this study, has used much the same framework in developing an allocation of Highway Costs for the State of Ohio.

The essential method rests on the premise that the structure of a "basic" roadway can be determined for a given volume range of traffic, that will accommodate repetitions of axle loading by a defined "basic" vehicle. Four





or five volume classes of highways have usually been chosen. The highest class, Type A, is the only one assumed to accommodate vehicles imposing repetitions of the maximum legal axle load. (The use of axle loads as a criterion determining the need for thicker and more costly pavement develops from recent road tests which have proven this fundamental axle-load, thickness, relationship for both flexible and rigid pavement.) Within this volume class, increments of cost are distributed to intervals of axle loads between the maximum legal and the "basic" - in Mr. Pancoast's study, 4 kips - as the thickness of pavement structure, width of surface, width of shoulder, cost of shoulder treatment, etc. is assumed to decrease as necessary to accommodate load intervals of smaller magnitude. The engineer using the approach is faced with this problem in consideration of facilities not actually constructed: What thickness of pavement and type of related structure would be required in this volume class if traffic were composed of passenger cars only; or, to designate the next highest standard, if traffic were composed of vehicles imposing no more than 6K axle load; and so on.

The contributing members to the Highway Research Board have demonstrated that their individual judgment, or the judgment of the agency they represent, differs considerably in answering the problem. Considering passenger cars only, some engineers are, undoubtedly, influenced by the standards to which high-volume parkways are constructed. Others are influenced by the standard of construction which must be applied to combat the effect of the elements. No criticism of the framework which poses these problems is intended. A rigorous analysis, not subject to argument and debate at some point, has not yet been devised. However, a uniform assessment of responsibility to different weight groups of vehicles will not necessarily follow general adoption of the framework under consideration by the Highway Research Board. For every difference in judgment as to what constitutes a "basic" facility for a volume group, a different scale of relative responsibility will result.

The next highest volume class of facility, designated as Type B, under the framework of the above analysis, is not considered to accommodate sufficient repetitions of the maximum legal axle load so that it has an effect on the required highway structure. Although maximum legal axle loads are considered, they are charged with the same relative responsibility as the next lowest axle-load interval. Distribution of cost is made in the same way as for the Type A facility.

Type C facilities are handled in the same manner. In this case, axle loads greater than those for which the facility is primarily designed are charged with the same weight-effect as loads for which the facility is designed. This progressive reduction of weight charge, as volume accommodation provided by the structure becomes less, produces a triangular pattern of analysis. A rectangular pattern, where the full weight-effect of the vehicle is considered on all facilities, is also possible. However, this does not take into account the number of repetitions of axle load which is of considerable significance in design. A structure built to accommodate innumerable repetitions of a ten kip axle load will also accommodate some limited number of repetitions of an eighteen kip axle load. The amount of use that a heavy vehicle makes of a low-volume



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facility will probably not produce sufficient repetitions of its axle load to fail the structure before it deteriorates from other cause. Therefore, the full weight-effect of the vehicle will not influence the structural design of this facility. At the same time, since design is largely a matter of engineering judgment, allowance is undoubtedly made for the greater weight-effect of the heavy vehicle. Since it is impossible to determine, with any degree of exactness, the extent to which this weight-effect influences structural requirements, the triangular distribution is more fair than the rectangular, but is definitely lenient towards heavy trucks. The triangular pattern will be discerned in the Montana analysis.

The distribution which has been described is for pavement cost alone. One of the essential considerations in this approach is the width of surface required by a given vehicle type. The defined "basic" vehicle is thought to require less width of travelling way. The assignment of grading and drainage cost in the Ohio analysis is based on the ratio of graded structure required to accommodate the "basic" vehicle to that required to accommodate trucks wider than the "basic" vehicle. A progressive assignment of these costs by weight is not made. A certain percent of cost is attributed to the "basic" vehicle; the remainder is shared alike by all other vehicles.

The Ohio analysis does not treat Type D facilities incrementally. These are non-surfaced roadways and weight is considered to have no effect in their structural requirements.



The framework of the Highway Research Board and Ohio solution may be simply illustrated as follows:

Standards are determined by construction practices.

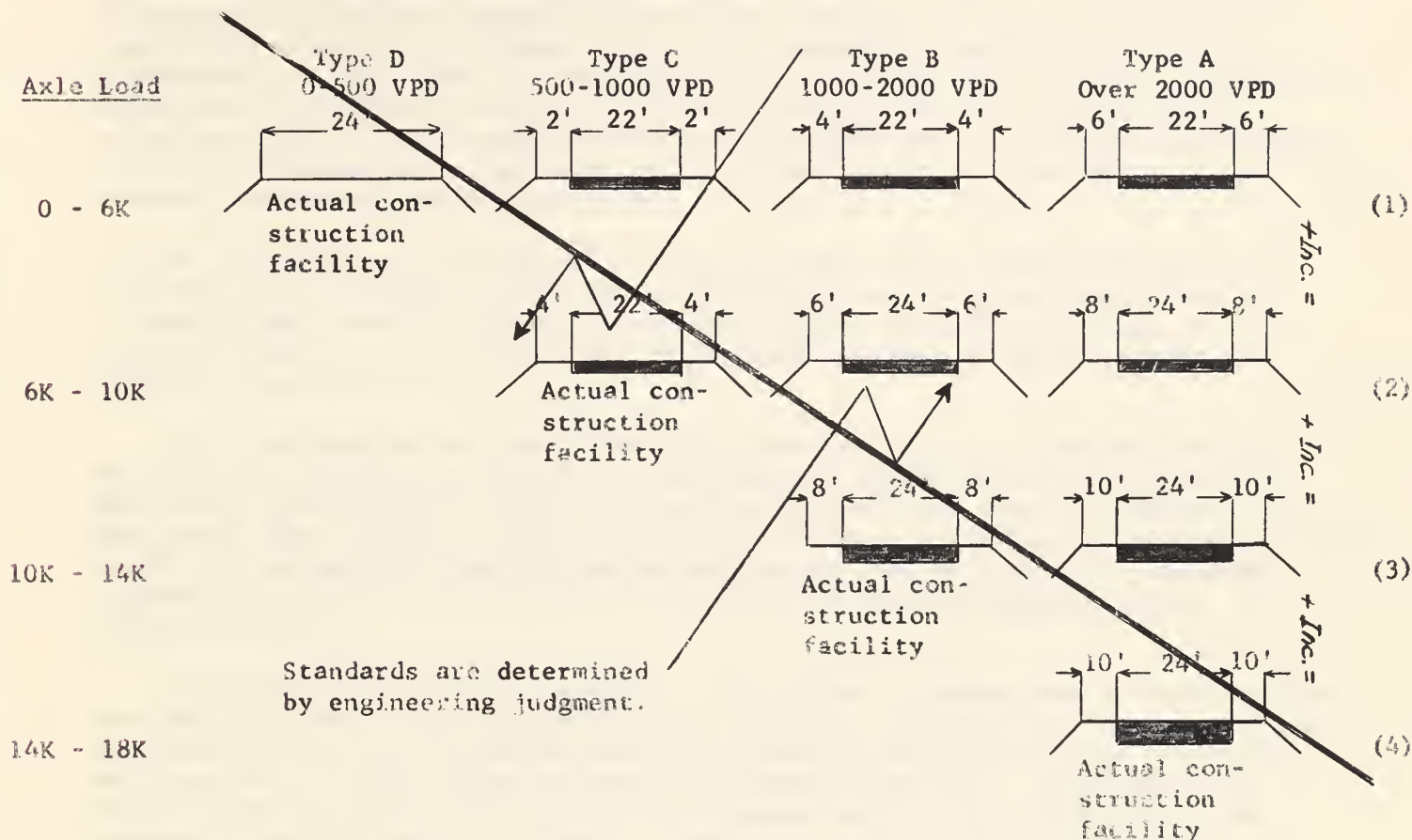


Figure 1.

Taking Type A as an example: The basic pavement (1) is charged to axle loads between 0 K and 18 K; the increment of cost between (1) and (2) is charged to axle loads between 6 K and 18 K; the increment between (2) and (3), 10 K and 18 K between (3) and (4), 14 K and 18 K. Eighty (80) percent of grading and drainage costs are charged to 0 - 6 K; 20 percent charged equally to all vehicles larger than those imposing 6 K. Maintenance is partially distributed by weight as determined by a multiple correlation and regression analysis; partially to all vehicles alike. Structures are treated incrementally by matching to above facilities, and distributing incremental costs in the same manner. Type D highways are not treated incrementally.

When dealing with Type B highways, the upper axle load interval, instead of reading "10K to 14K", should read "over 10K". By means of the illustration and example given, it is intended only to show the fundamental framework of analysis used in Ohio and considered by the Highway Research Board Committees.





Although the above approach to the incremental solution is entirely scientific, it is not proposed to abide entirely by its framework in the Montana analysis. One of the reasons a departure is contemplated is the amount of engineering judgment required to determine basic factors. In addition, the wide surface width designated for low-volume roadways in this State precludes consideration of width increment, since this geometric standard is chosen to accommodate the high speed of passenger cars. It is thought that the controversial definition of a "basic" vehicle, or "basic" facility can be avoided, and the solution which will be proposed avoids these definitions. In the Montana proposal, it is not so necessary to separate and individually describe the benefits of certain elements of construction cost.

So that the point of view of commercial users of the highways will not be overlooked in the Montana solution, consideration and study has been given to a recent report made by the Virginia Highway Users' Association, which incorporated both a cost function and incremental analysis designed to test tax equity in that State. (1)

It is noteworthy that the fundamental approach to the incremental analysis contained in that report is that of consideration of the actual facilities constructed in that State, rather than "mythical" facilities deemed necessary to meet needs when conditions other than reality exist. A similar "practical" approach in the Montana solution should prevent contention that an individual engineer's judgment has resulted in unfair tax allocation to the disadvantage of the commercial user.

An extensive breakdown of current construction and maintenance costs provides the basis for the Virginia Highway Users' solution. Elements of construction and maintenance cost are assigned separately, either as weight functions or general use functions. Axle loading is used as the weight criterion. Increments for width, pavement thickness, gradient, structures, and related maintenance, are assigned to weight-responsible vehicle groups. It is interesting to note that the potential of a vehicle to impose a given axle load is used in the pavement thickness assignment.

No special effort is made to relate a class of roadway to a vehicle-group accommodation, except that the State Class I highways are described as the predominate truck routes, and Class 2 highways as "mixed traffic" high-volume routes with a smaller proportion of truck traffic. Much the same standard of facility is provided for these two classes except for surface which is two feet wider on Class I, and gradient requirements which are more demanding on Class I.

These differences are attributed to the larger proportion of trucks on Class I, and comparison of these two facilities produces, first, an increment of width

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(1) Testing the equity of Virginia's Motor Vehicle Tax Structure - a Report to the Commission Established by Senate Joint Resolution Number 48. Submitted by the Virginia Highway Users' Association, June 1953.



for both surfaces and total graded structure, and, second, an increment of gradient for construction of the total graded structure. These increments are exclusively assigned to trucks, and essentially distributed by proportionate vehicle miles. Differences in surface width between Class II and Class III, and between Class III and Class IV routes of the Primary System are not considered attributable to weight or size. These are progressively lower volume routes.

All remaining pavement construction cost and related maintenance cost, for the Primary System, is distributed by weight-apportioned increments. About 60 percent of the maintenance of pavement on the Secondary System is distributed in the same way. However, construction cost of pavement on the Secondary System is not at all attributed to weight or size, presumably because this system is composed chiefly of local rural county roads.

Structures on all systems, primary and secondary, are essentially treated by weight criteria. The cost of all "basic" facilities, primary and secondary, and administrative expense is distributed by relative use, or vehicle miles.

At first glance the solution appears to be entirely equitable, in fact to work adversely for the heavy vehicle. Actually, it is "weighted" in favor of the heavy vehicle. The authors make much of the distribution of one or another cost factor entirely to trucks, when the accommodation provided would suggest a more equitable distribution. Actually, the proportion of costs unfairly distributed to the heavy vehicle, to the overall construction and maintenance cost, is small. On the other hand, a "weighting" of the solution in favor of trucks is inherent in the handling of pavement thickness.

Different types of pavement construction on the several facilities are not recognized, and pavement cost is made proportional to thickness entirely. This results in a very high relative standard for "basic" vehicle or passenger car accommodation. Analysis of non-partisan solutions in other States indicated the assignment to passenger cars may be as much as ten percent too high. The lack of consideration of weight effect on the underlying structure tends to destroy the argument of equitability. Also, although considerable passenger car mileage must have been travelled on the 40,000 miles of Secondary System by definition, this mileage is not subtracted when apportioning the cost of the "basic" facility in the relatively high-cost Primary System.

Class I and II highways only are compared for width increment, when, in fact, design standards cited call for less surface width on Class III and Class IV. Partly because of the high relative "basic" pavement on the Primary System, heavy vehicles are not considered responsible for any element of construction on the Secondary System, although one-third of that system is hard-surfaced.

A cost function analysis is presented along with the incremental analysis. The fundamental concepts applied to each are, to a degree, contradictory. In the cost-function analysis, engineering and administrative costs are defined





as "standby" costs, and argument is presented that these costs should not be distributed by relative use or vehicle mile criteria. They are apportioned by registration. In the incremental analysis, all of these costs are apportioned by relative use. Since the proportions by travel are different than the proportions by registration, (trucks generally travel more miles per vehicle), the cost function approach favors heavy vehicles in this respect.

There is no reason to divorce concepts applied to the incremental method from those applied to the cost-function method. An incremental analysis, to consider all aspects fairly, must incorporate the cost function approach. Some costs are fairly separated from relative-use or weight criteria, and should be charged on the basis of vehicle registration. The cost of collecting registration fees is an example. Payments to related departments and agencies, legal fees, grounds and buildings, some aspects of planning surveys, etc. bear little relationship to the relative use of facilities. Beautification and landscaping should probably be charged to passenger cars only.

However, engineering and administrative costs directly related to construction or maintenance are not different in character from pavement or grading item costs. If it entails more engineering and administrative expense to construct or maintain thick pavement than it does to construct and maintain thin pavement, a certain proportion of these costs may actually be weight functions. The administrative and engineering expense of constructing and maintaining the "basic" facility is reasonably distributed by relative use.

In the Montana analysis an approximate distribution of administrative expense by function will be undertaken. This will be accomplished by a process of elimination. First, administrative expense in no way related to the relative use of highways will be separated. Since there are not many costs in this category, this will not be too difficult a task. Second, "direct" engineering cost of construction and maintenance will be separated. (These costs are generally a fairly constant proportion of contract or force account construction and maintenance costs). These costs will be added to other costs of the facility considered, which will automatically cause them to be distributed incrementally. Remaining administrative costs will be apportioned along with the cost of the "basic" facility by relative use, or vehicle miles.

Before proceeding with the description of the Montana method, earlier investigations should be mentioned, which are notable for their contribution to present-day thinking on the incremental problem. They are as follows:

1. Report of the Interim Committee appointed by His Excellency, Charles H. Martin, Governor of the State of Oregon, for a study of the Motor Transportation Act and the fees and taxes paid by the



Road Users for the Highway Facilities provided  
by the State of Oregon - January 1, 1937.

2. Public Aids to Transportation, Volume IV, Public Aids to Motor Vehicle Transportation - Federal Coordinator of Transportation, 1940. (Often referred to as The Eastman Report).

Although other analyses have been made by the incremental method, both in the United States and in Canada, contributing to detail and structure, these have not been studied in detail since the fundamentals applicable to present studies have been "sifted" from the respective reports by Mr. Pancoast, Mr. St. Clair and others.

The Montana Solution

The Montana solution is being prepared under the auspices of the Montana Fact Finding Committee on Highways, Streets, and Bridges, in cooperation with the State Highway Department. The method of analysis is essentially designed to reflect present construction practice and engineering viewpoint in the State. As has already been stated, certain problems of highway construction and finance are peculiar to each State. An incremental analysis designed to fit the needs of the heavily populated eastern states would not, in all probability, result in a reasonable allotment of highway cost if applied in Montana.

Montana's peculiar problems arise from its topography which embraces extremes of very flat to very mountainous terrain; from its lack of densely populated centers which results in few high-volume traffic arteries; from its many attractions for tourists which results in a relatively large number of out-of-state vehicles on its highways; from the predominance of two major industries, farming and mining, which results in greater load applications on low-volume highways; from its situation with respect to other States and the mountain barrier. Highway costs, especially high in mountainous terrain, must be distributed among relatively few domestic highway users.

What, then, is desired, is a reasonable allotment of highway costs that will bear a scientific relationship to the use of highways by different vehicles imposing different conditions on the highway structure. It has been amply demonstrated that no method of analysis can rigidly fix responsibility for all elements of highway cost.

The basic premise of the Montana method of incremental allotment of highway costs is that each standard of facility constructed on a homogeneous highway (1) system is a "stage" in the construction of the next highest standard of facility. This premise is supported from a historical point of view by consideration of the manner in which highway systems have developed. Essentially, it has been a process of improving existing facilities to accommodate a more demanding traffic picture.

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- (1) Each homogeneous highway system will be treated separately under the headings: Federal Interstate, Primary, and Secondary, without regard for administrative jurisdiction. Local rural roads and city streets are excluded from the determinations which follow. These systems will be studied separately. See the end of this text for further discussion.





As population centers have grown and as the efficiency of motor vehicles has been improved, it has been necessary to build connecting roadways to ever increasing geometric standards to accommodate more vehicles at higher speeds. As the use of highways for the transportation of freight has increased, it has been necessary to devise stronger structures to accommodate the heavy vehicle. New facilities may or may not have been built on top of existing roadbeds, but, regardless, they constitute improvement of existing facilities. The process still continues.

It is desirable to relate this process to the present program of highway construction which is expected to provide adequate highway facilities in this State within the next 20 years. Relative responsibility between motor vehicle users will be developed for a total highway product that will fit their needs. Although construction costs applied will be those estimated for the 20-year program, the relative responsibility so developed can be applied to a shorter range objective. The validity of the solution should last until a totally different pattern of highway needs becomes apparent.

Instead of defining a "basic" vehicle, or a "basic" facility as such, a base mean standard will be chosen, as actually constructed in the State, which will be related, by engineering judgment, to the accommodation of a specific upper limit of axle loading.

The base mean standard chosen for this analysis will be the facility which the Automotive Safety Foundation on the basis of AASHO recommendations considers adequate to accommodate a volume of traffic from 200 to 400 vehicles per day in the State of Montana.\*

The Automotive Safety Foundation and engineers of the State Highway Department have been influenced, in choosing geometric standards for this accommodation, by certain characteristics of motor vehicle operation peculiar to Montana. Although there are night-time speed limits, and zones of limited speed, there are no further restrictions on the speed of passenger cars in this State. Trucks are limited to 45 mph. As a result, average operating speeds are from 5-10 mph. higher than the national average. As a result of high expected speeds, a 24-foot width of travelling surface is the absolute minimum to be constructed on any highway. State engineers are insistent that this width of travelling surface on low-volume facilities is necessary to accommodate the high speeds of passenger vehicles regardless of the composition of traffic. It therefore follows that there is no increment of width for pavement structure chargeable to heavy vehicles. Montana's highway engineers have found certain decided advantages in using plant-mix pavement rather than road-mix or penetration-type pavements. The choice of a 24-foot minimum width of paved surface has been influenced, to some extent, by this consideration to prevent ravelling of plant mix on the shoulders.

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\* Table III. Design Standards for Rural State Highways



Since factors other than capacity dictate geometric requirements for the 200-400 VPD facility, data from the Highway Capacity Manual has been applied to determine the potential of this basic mean standard at the operating speeds which are applied to the design of the highest standard two-lane facility. Since operating speeds of 50-55 mph are presumed for level terrain, the maximum restrictive conditions designated for the 200-400 VPD facility in level terrain are investigated. The capacity of this facility at these speeds under ideal conditions is 600 vehicles per hour. Because there is little reason that passing sight distance should be restricted in Montana's level country, 20 percent restricted sight distance is conservatively chosen. This reduces practical capacity to 560 vehicles per hour. The Automotive Safety Foundation, following AASHO recommendations, specifies 6-foot shoulders for this facility. (1) Since this allows no lateral clearance from the pavement edge, there will be a reduced capacity in the immediate vicinity of a vehicle stalled on the shoulder. The effect that an occasional disabled vehicle would have on the practical capacity of an entire highway is difficult to measure. Traffic engineers, consulted for this determination, have expressed the opinion that 5 percent reduced capacity is ample allowance for one such obstacle per mile. In order to produce the axle load which will relate to the basic mean standards, it is assumed that structural accommodation is essentially provided for vehicles up to 5 tons Gross Vehicle Weight. The presence of these small commercial vehicles may reduce potential capacity by five percent. Applying these last two factors, we arrive at a potential capacity of 500 vehicles per hour, or 4,000 vehicles per day on the facility designed to accommodate from 200-400 vehicles per day. The 475-foot stopping sight distance chosen for the low-volume facility is adequate for speeds of 52 mph on wet pavement. Medium-powered trucks of 5 tons Gross Vehicle Weight can negotiate a five percent grade, one thousand feet long, at speeds close to 40 mph. Since the number of grades of this magnitude and length will not be large in level country, the choice of a maximum 5 percent for the 200-400 VPD facility will not have much effect on its practical capacity. The maximum 6 degrees of curve chosen can be negotiated at speeds over 50 mph on a 12-foot lane.

Similar analysis of the basic mean standard in mountainous terrain, discloses a practical capacity somewhat less than 4,000 VPD if operating speeds are maintained. However, operating speeds on the highest type two-lane facility must be compromised for economic consideration in this topography, and design standards so allow. With the same degree of compromise, the potential practical capacity of the 200-400 VPD facility again becomes 4,000 vehicles per day provided only passenger cars and light trucks are accommodated.

Consider the practical maximum capacity of any two-lane facility accommodating all mixed traffic. If high operating speeds are to be maintained with the same degree of safety provided on lower volume structures, this capacity is not far above the 4,000 VPD accommodation. Although it may not be economically feasible to construct multi-lane facilities in all cases where this amount of traffic has developed, there is still a real need for their employment for volumes in excess of

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- (1) The fact that it may not be economically feasible to immediately construct this width of shoulder need not be considered, since responsibility is developed for a standard product that will be adequate in twenty years.







4000 vehicles per day. In mountainous country, engineers will, undoubtedly "upgrade" facilities carrying anywhere near this volume from two-lane to four-lane rather than construct extra climbing lanes. In level country, on high volume routes, the costs of multi-lane construction will not be so prohibitive. Therefore, for the purpose of this analysis, 4000 vehicles per day is assumed to be the normal upper limit of accommodation of any two-lane facility with a twenty-four foot travelling surface. Any prejudice against a heavy vehicle which may appear to arise from this assumption will be outweighed in the analysis since "upgraded" facilities will not otherwise be considered as a charge against trucks.

Since the basic mean standard facility is capable of accommodating 4,000 VPD of passenger cars and light trucks, and the maximum accommodation provided by two-lane facilities is 4,000 VPD of mixed traffic, it follows that every difference in structure between the mean standard and highest type two-lane facilities is chargeable to heavy vehicles. Axle load is the weight criteria usually applied to determine relative responsibility and will be used in this analysis.

Before proceeding further, it is well to examine the structural and geometric differences between a 200 VPD accommodation and a 4,000 VPD accommodation to determine how they relate to weight when factors other than potential capacity are considered. It is necessary to anticipate, to some extent, the form of analysis herein proposed, so that charges that will develop against heavy vehicles may be viewed in proper perspective.

Differences in the following elements of roadway structure will occur between the two accommodations: pavement structure; type of pavement; thickness and type of base; and width and treatment of shoulders. No argument need be advanced to prove that the first three are legitimate weight charges. In consideration of the width and treatment of shoulders, the results of the WASHO Road Test are significant. Roadway shoulders, stabilized and paved in accord with present construction practice, serve but three purposes. They prevent moisture from collecting beneath the pavement. They provide parking area off the travelled way for disabled vehicles. They contain materials in the underlying structure to prevent breaking of pavement in the outer wheel path. Bituminous treatment of the six-foot shoulder on the "basic mean standard" will effectively seal off moisture. This width of shoulder is sufficient to provide for a disabled passenger car or light truck, without unduly hampering traffic. Wider and stronger shoulders must be provided, however, for wide and heavy trucks. The WASHO road test demonstrated that heavy vehicles occasion the need for more stability in the outer wheel path. Therefore, the extra four feet of shoulder width constructed on facilities accommodating large volumes of mixed traffic is mainly a size and weight requirement.

In addition to the differences in the structure of the roadway prism, there are differences in gradient and alignment between the two accommodations. The effect of the heavy vehicle in requiring these differences, therefore, needs consideration. It is difficult to affix responsibility for better gradient because of the pronounced effect of heavy vehicles in retarding traffic on all but the lightest grades. However, a reasonable apportionment of grade costs by weight will result from comparison of the 200 VPD accommodation and the 4,000 VPD accommodation, certainly





without prejudice to the heavy vehicle. Since passenger cars can negotiate long 6 and 7 percent grades at speeds above 30 mph, which is the optimum speed for maximum capacity, and since medium powered trucks of 5 tons or less, Gross Vehicle Weight, can sustain this speed, it is reasonable to assume that grades of this magnitude would be adequate in areas of costly construction if traffic were composed of these vehicles alone. The difference in cost between the 5 percent maximum grade and 3 percent maximum grade designated for 200 VPD accommodation, and 4,000 VPD accommodation, respectively, in level terrain; and the difference in cost between 7 percent maximum and 6 percent maximum in mountainous terrain, is certainly a reasonable amount to apportion by weight. This charge against the heavy vehicle is undoubtedly lenient.

Comparison of alignment between the two accommodations also produces a reasonable proportion of cost to be distributed by weight. The following argument supports the contention that the basic mean standard, 200 VPD, roadway would provide the same accommodation for light vehicles that the 4,000 VPD accommodation will provide for mixed traffic.

Considering flat topography, very little difference in alignment will occur between the two standards. Little economic advantage is to be gained by constructing sharp curves and short tangents in Montana's treeless flat country. For any difference in cost that does occur, the heavy vehicle has sufficient effect on the traffic flow to require the highest standards of alignment that are economically feasible. Large vehicles in heavy traffic definitely restrict passing opportunities even when adequate sight distance is provided. This effect occurs because of the difficulty of seeing beyond a wide truck, and is supported by Highway Capacity Manual data, which states that one commercial vehicle has the equivalent effect on traffic of  $2\frac{1}{2}$  passenger cars. Trucks, and all traffic hampered by their presence, benefit from good alignment approaching short three or four percent grades, since it allows heavy vehicles to make a running start sustaining maximum speeds. There is sufficient warrant in these considerations to apportion by weight the small difference in alignment cost between the two accommodations in flat topography.

At the other extreme, in mountainous terrain, it also develops that comparison of alignment provides a fair measure of cost distributed by weight. Consider the basic mean standard accommodation in an area where every improvement in alignment entails considerable cost. With traffic comprised of light vehicles capable of sustaining 30 mph climbing speed, it would hardly be necessary to provide passing opportunity. This speed will not unduly hamper a passenger car under these conditions. The 12 degrees of curve designated for the basic mean facility is adequate for climbing speeds above 30 mph and, therefore, provides sufficient accommodation for large volumes of passenger car and light truck traffic. The higher standards of alignment designated for a facility which might accommodate 4,000 VPD of mixed traffic will not allow more than 30 mph climbing speed where limiting design standards are used for economic reasons, since passing sight distance is only provided every mile and a half. The reduction in curvature to





7° will increase the climbing speed of heavy vehicles on grades of medium length, since reduced tractive force spent in negotiating sharp curves will allow the use of higher gear ranges. The amount of sight distance provided, and the reduced curvature, will probably allow the bulk of traffic to proceed at speeds near 30 mph. The main difference in accommodation provided by the 4000 VPD facility is in the provision of ten percent passing sight distance. It may be of interest to develop a measure of the cost that will accrue to heavy vehicles under these conditions. The 12° of curve designated for the basic mean standard requires a 20-foot middle ordinate to a cut clove. To provide one passing area with the same middle ordinate would require that this degree of curvature be reduced to 1° 30'. That this will entail a great deal more cut and fill in some instances is apparent.

The foregoing comparison assumes a condition where limiting standards of design are applied. With less than maximum gradient, in rolling terrain, for example, traffic which includes the heavy vehicle does not benefit to such an extent by better alignment; however, the form of analysis proposed mitigates these charges against trucks by making the following allowances. The full weight-effect of heavy vehicles on low and intermediate volume structures is not considered - and trucks will be charged at an axle load rate which is less than that they actually apply. Account is not taken of facilities which are "upgraded" from two-lane to four-lane by the presence of heavy vehicles. The heavy vehicle's responsibility for gradient is minimized. Weight charges are distributed over a wide range of axle loads.

An additional premise is now developed from capacity data and practical consideration; that the geometrics designated for the "basic mean standard" 200 to 400 VPD accommodation are sufficiently high that comparison of this standard with the highest type two-lane facility will produce elements of construction cost entirely assignable by size and weight.\*

Since the 200-400 VPD facility is the basic mean standard, it is now necessary to relate its structure to an axle loading which may be applied in innumerable repetitions without harmful effect. For a paved structure, 14 inches in total depth with two inches of plant mix on a crushed gravel base, an axle load of 6 K is chosen. The highest type of paved structure, built on a roadway which will carry over 2000 vehicles per day, is designed to accommodate repetitions of the maximum legal axle load. The Automotive Safety Foundation has designated in-between volume "classes" which will carry their own structural requirements. Each is related to a maximum axle load accommodated as follows:

Axle Load Interval (Kips)	Volume Accommodated (VPD)
- 6	200 - 400
6 - 10	400 - 1000
10 - 14	1000 - 2000
14 - 18	2000 - 4000

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\* This premise applies only to the roadway itself. The costs of obtaining and marking right-of-way; other costs of controlling access; beautification and provision of recreational facilities, etc. will be subtracted from the weight apportionment.



According to the basic premise, the 200-400 roadway is included in all higher volume roadways as a "stage" in their construction. Therefore, the total mileage of the 200-400 VPD facility considered in the analysis is the mileage of all two-lane facilities accommodating 200 VPD upwards in any homogeneous highway system. (1) The total mileage of the 400-1000 facility is the mileage of all two-lane facilities in the system accommodating more than 400 VPD, and so on. The estimated cost per mile of constructing each standard will be determined from Automotive Safety Foundation and State Highway Department cost determinations. The differences in cost per mile between standards will be incrementally assigned to vehicles in accordance with the axle loads they impose. The total cost of the weight-assigned structure in a system will be later determined by multiplying vehicular responsibility per mile of any standard by the number of miles of that standard figured as above. The details of this distribution and reintegration will become apparent as the discussion continues.

Vehicles will be grouped under different types by Gross Vehicle Weight classification. The maximum potential axle loading of each Gross Vehicle Weight class will be determined. Each axle load will be first applied to its own interval and related roadway increment according to its potential. It will then be applied to each increment below its own requirement, assuming the proportions of the maximum axle load in the interval related to that increment. The load on each axle, as applied in each interval, (or related increment), will be multiplied by the vehicle miles that the related Gross Vehicle Weight class travels on the facility in the system which includes that increment. This establishes a relative measure of use of the interval. Mileage projected to mid-point of the program period will be used. Table I illustrates the distribution. The increment of cost per mile of construction that is required to accommodate each increasing axle load interval is developed as follows:

#### DEVELOPMENT OF INCREMENTAL COSTS

Volume Class (V.P.D.)	Construction Cost Per Mile (\$)	Increment of Cost Per Mile (\$)	Axle Load Accommodated (Kips)
200 - 400	30,000		
400 - 1000	45,000	15,000	6 - 10
1000 - 2000	56,000	11,000	10 - 14
2000 - 4000	66,000	10,000	14 - 18

This cost will then be apportioned by kip-axle-miles to axles using the increment. All of the figures are for illustrative purposes only.

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(1) See footnote, page 9.





TABLE 1

FIGURES FOR ILLUSTRATIVE PURPOSES ONLY

TYPE OF VEHICLE BY G.V.W. CLASS	NO. AXLES IN GROUP & AV. MAXIMUM LOAD		ANNUAL VEHICLE MILES (X1000)	ANNUAL KIP AXLE MILES (X1000) @\$ .011111	ANNUAL VEHICLE MILES (X1000)	ANNUAL KIP AXLE MILES (X1000) @\$ .007333	ANNUAL VEHICLE MILES (X1000)	ANNUAL KIP AXLE MILES (X1000) @\$ .003125	ANNUAL VEHICLE MILES (X1000)	ANNUAL KIP AXLE MILES (X1000)	ANNUAL VEHICLE MILES (X1000)	ANNUAL KIP AXLE MILES (X1000) @\$
	FRONT	INTER REAR										
FARM TRUCKS												
40,000 - 38,000	1@8	2@16			450	14400	900	25200	1100	30800	1600	28800
38,000 - 36,000	1@6	2@16			700	22400	1600	44800	2400	48000	3500	63000
36,000 - 34,000	1@6	2@15			600	18000	2500	120000	3500	70000	4000	72000
34,000 - 32,000	1@6	2@14					6000	168000	9000	180000	12000	216000
32,000 - 30,000	1@5	2@13					7000	182000	9000	180000	12000	204000
30,000 - 28,000	1@5	2@12					7000	168000	10000	200000	13000	65000
30,000 - 28,000	1@11	1@18			400	7200	2000	50000	2500	50000	4000	48000
28,000 - 26,000	1@10	1@18			700	12600	3000	42000	4000	80000	6000	72000
26,000 - 24,000	1@8	1@18			1500	27000	4000	56000	6000	108000	12000	144000
ETC.												
COMMERCIAL TRUCKS												
42,000 - 40,000	1@10	2@16			600	19200	1200	33600	2200	66000	5000	90000
ETC.												
SEMI-TRAILERS												
32,000 - 30,000		2@16			2200	70400	3500	98000	5000	100000	7000	84000
ETC.												
18,000 - 16,000		1@18			4000	72000	6000	84000	9000	90000	12000	72000
ETC.												
FULL TRAILERS												
48,000 - 46,000	1@14	2@16			800	25600	900	37800	1100	33000	1200	21600
ETC.												
8,000 - 6,000		2@4									50	400
ETC.												
TOTAL CUMULATED THOUSAND-POUND AXLE MILES				900000				1500000		4800000		50500000



# APPORTIONMENT OF INCREMENTAL COSTS

Volume Group Accommodating Axle Load Interval	Annual Kip-Axle Miles (x 1000)*	Increment of Cost Required (\$)	Increment Cost per Thousand Kip-Axle-Miles (Cents)
200 - 400	50,500,000	Developed by Different Process	
400 - 1000	4,800,000	15,000	.31250
1000 - 2000	1,500,000	11,000	.73333
2000 - 4000	900,000	10,000	1.11111

\* From Table I.

The use of kip-axle-miles, or thousand-pound axle miles, is a new concept in this analysis. It has the effect of distributing the responsibility within each interval by weight, so that vehicles near the borderline of decreased responsibility are not penalized in favor of vehicles near the borderline of increased responsibility. The use of potential axle loads, to be determined from a vehicle's registered weight, is considered a better criterion of its responsibility in the requirement of higher-standard roadways than the use of axle loads actually imposed which might be derived from loadometer data. The public cannot be expected to underwrite uneconomic operation.

It will be noted that to this point only the weight responsibility of vehicles imposing more than 6 K axle load may be determined. The argument supporting the use of kip-axle-miles stated that this criterion avoided penalty near the borderline of weight responsibility. To extend this argument further, the weight-charge against each larger axle load should increase on a fairly uniform curve. This is both desirable and reasonable for tax allocation. And it is practical to develop a uniform curve of increasing weight responsibility by the following procedure. Having determined the relative responsibility per kip-axle-mile for axle load intervals with divisions at the upper limits of 10 K, 14 K, and 18 K, it is possible to plot the responsibility so determined on axes representing these loads. The curve so developed, may be mathematically extended to cut the 6 K axis and establish a weight-cost at that point. This cost will be the charge per kip-axle mile for some undefined increment of construction accommodating axle loads between 2 K and 6 K. It will be applied to this interval in Table I. Although the foregoing responsibility is not rigidly defined, it is a reasonable development, avoiding penalty to vehicles on the borderline of responsibility, and in keeping with the trend of increasing weight responsibility.

It is not necessary or practical, to define weight responsibility for vehicles with 2 K or less axle load. Gross Vehicle Weight classification does not apply below 6000 pounds. Vehicles with axle loads of 2 K or less travel 75 percent of all mileage on our highways. By neglecting weight-responsibility





in this bracket, the effect, by the method of elimination developed in this analysis, will be to transfer any weight-cost chargeable to this group to the cost of the undefined basic highway required by all axle loads, which will be distributed in the ratio of their annual travel by vehicle-miles. (Non-weight-use costs.) Vehicles with axle loads to and including 2 K will bear the largest share of the cost of the basic highway: ergo, they will bear the largest share of weight-cost so transferred.

Multi-lane facilities, assumed to be necessary to properly accommodate any volume in excess of 4,000 VPD, will be handled as follows. Each additional two lanes will be considered, structurally, as equivalent mileage of the highest-type two-lane facility. This mileage will be multiplied by the unit responsibility of each Gross Vehicle Weight class for this standard, as developed from Table I. The sum of these charges is then the "weight-charged" portion of the total cost of the multi-lane highway. The remaining portion, the cost of medians, right-of-way, control of access, etc. will automatically fall in the cost of the residual, or basic, highway which will be charged to all groups by vehicle miles.

Where an additional climbing lane is provided, because operating speeds are reduced by the presence of slow trucks, its cost will be determined and distributed separately. State Highway engineers have pointed out that these additional lanes, although required where heavy vehicles are present, are not exclusively provided for their accommodation. If passenger cars and lighter trucks were willing to slow down, their provision would not be necessary. The accommodation is largely to maintain the operating speeds desired by operators of the lighter vehicles. The ideal solution to the problem of distributing the cost of these climbing lanes would be a solution in which the effect of the slow-moving vehicle on decelerating traffic would create a "weighted" assignment of cost against them. Fortunately, such a solution is easily derived from a practical and provable standpoint, and as easily applied.

Highway capacity studies have derived the equivalence of trucks in terms of passenger cars on various grades. As an example: if, on a 7 percent grade, of a given length, it is found that one truck, of a given type and weight, has the same effect on decelerating traffic as 10 passenger cars; and if it is found that the same truck on level grade is equivalent to 2 passenger cars, it has five times the effect in decelerating traffic than it is already paying for in the incremental distribution. This truck and passenger car will then be charged with the additional cost of the climbing lane at a ratio of 5 to 1.

Having determined to this point the unit responsibility of each Gross Vehicle Weight class for each weight-apportioned increment of roadway in a system, it is now possible to sum all of these costs to obtain the part of the total cost assigned by weight. For example: Commercial trucks in the 34,000 to 36,000 Gross Vehicle Weight class have axles which travel 140,000 thousand kip-axle-miles on the standard accommodating 14 to 18 kips at 1.11111 cents per mile of this standard constructed; 260,000 thousand kip-axle-miles on 10 - 14 K at 0.73333 cents per mile of construction; 400,000 on 6 - 10 K at 0.31250 cents; 600,000 on 2 - 6 K



at 0.07321 cents. There are 400 miles of 14 - 18 K, which includes equivalent mileage of four-lane facilities; 1500 miles of 10 - 14 K, which includes the 400 miles that this standard is a "stage" of the 14-18 K accommodation; 2500 miles of 6 - 10 K which includes the 1500 miles of higher standard; and 4,000 miles of 2 - 6 K, which includes the 2,500 miles of all higher-type facilities. Then, the weight charge assigned to this vehicle group is  $(1400 \times 1.11111) 400 \div (2600 \times 0.73333) 1500 \div (4000 \times 0.31250) 2500 \div (6000 \times 0.01321) 4000$  or \$8,364,250. The sum of weight charges assigned to each vehicle group is the total weight-cost of the constructed system. All figures used in the above example are illustrative only.

To the weight-cost, determined as above, will be added the cost of additional climbing lanes which will be separately assigned; of beautification, landscaping, waysides, picnic sites, historical markers, and other recreational facilities with appropriate signs, which will be separately assigned to passenger cars. The result will be subtracted from the total cost of all construction on the system to leave a residual which must be on the cost of the basic element of construction which is required and used by all vehicle groups alike. The cost of the basic highway will then be distributed to the vehicle groups in proportion to their use of the highway system, or, in other words, be vehicle miles.

This residual, which is the cost of the basic system structure since the analysis is performed separately by systems, will include the cost of sections of unsurfaced highway in the Secondary System. The resulting assignment of some cost to heavy vehicles for roads which they may not actually use is supported by the following considerations. First, it must be remembered that the Secondary System does not include local rural roads which represent 75 percent of all rural mileage. The Secondary System is designed to "feed" the Primary and Interstate Systems. Although heavy vehicles do not make use of unsurfaced feeder routes at this time, they may do so in the future, and are reasonably considered responsible for this "stage" in the construction process. From a point of view of economics, all State roads generate the product which is carried by heavy commercial vehicles on primary highways. To the extent that this is true, most, if not all, classes of highway user derive benefits from all roads, and should be charged with some proportion of their cost. Therefore, allocation of the cost of the basic structure in the main feeder system by relative use of the system as a whole is fair and just, even though the basic structure includes some roads which heavy commercial vehicles do not use.

#### Maintenance Cost.

The method of elimination developed in the handling of construction costs may be extended, practically, to the allotment of maintenance costs, so that it will not be necessary to consider each element of cost and the resulting benefits to one or another vehicle group. Each facility considered as a "stage" in the incremental solution has its prototype on the present highway system. Essentially, the process







will involve comparison of prototypes of the different standards for average annual maintenance cost. Each set of standards so compared will be similarly situated, so far as possible, with respect to topography, weather, and type of soil. The average annual cost of maintaining each prototype over a period of years will be computed. All costs which do not at all relate to the use of facilities will be subtracted in the derivation of this figure. These will include costs of landscaping, beautification of campsites, historical markers sidewalks and foot paths, etc. Costs not arising from the normal usage of highways such as the costs of major slide removal and washout repair, channel changes, riprap, etc., will be subtracted. The remaining average annual cost of maintaining each standard of facility will be multiplied by a factor so that the total cost of maintaining all standards will equal a sum estimated to meet maintenance expenditures on the system for the program period. This latter figure will be exclusive of costs of landscaping, beautification of campsites, historical markers, etc. which will be developed for the same period and separately charged to passenger cars. The total maintenance cost of each standard for the program period will then be added to the construction costs developed for each standard, before increments of cost are calculated for distribution to the several weight groups. Increments of maintenance cost chargeable by weight may or may not develop. The "residual" will automatically become the cost of maintaining the basic facility, and will be distributed by relative use.

#### Cost of Highway Structures

The cost of constructing major highway appurtenances, such as bridges over 20 feet in length and underpasses, will be allotted by the same method as the cost of constructing the roadway itself is allotted, although a separate incremental distribution will be necessary. For simplicity, underpasses will be considered as bridges on the upper highway. The average cost per foot of length of constructing a bridge that will "match" each standard of roadway will be determined. For example: H-20 loading is considered for the design of bridges accommodating over 2000 vehicles per day; H-15 loading for volumes between 200 and 2000 VPD; H-10 loading for less than 200 VPD. Here the weight relationship between different volume accommodation is apparent in the way it influences designers to select these different standards. Differences in width will result because of differences in shoulder width. Since the shoulder requirement is attributable to weight and the effect of heavy vehicles on traffic, so must the differing bridge widths be considered.

After costs are determined for each standard of facility, differences or increments of cost per foot of length will be computed. These increments will be distributed to each Gross Vehicle Weight class of vehicles of different types, using the same kip-axle-mile figures employed in the roadway analysis, substituting unit costs per foot of structure for unit costs per mile of roadway. A unit cost figure for the 2 - 6 K axle load interval will be developed in the same way. The unit vehicular responsibility in each axle load interval will be multiplied by the length of related structure in the system. A total weight-



distributed cost will be developed, and when this is subtracted from the total cost of structures in the system, the residual will be the cost of the "basic" structure, which will be distributed by relative use.

Tunnels are the only major structures which remain to be considered. The increments of cost in their construction will not be in the same ratio as average increments developed for bridges and underpasses. Because of the small number of these facilities that may be built, a separate incremental distribution of their cost will not be worthwhile. As an end result of the analysis, a chart will be set up showing the total of all charges against each Gross Vehicle Weight class of vehicle under the different type headings. By multiplying each cost by the same index, the cost of tunnels and miscellaneous costs not otherwise considered will be covered. In other words, the relative scale will not be influenced by their inclusion or exclusion, but a figure will be secured for the program period.

#### Administrative Costs

The proposed method of handling administrative costs has already been described. A minimum of selection is anticipated, and the usual method of elimination will be used. Those costs which can be directly related to the construction of various standards of facilities, e.g., a fixed proportion of construction cost for engineering, will be added to other construction costs before the incremental distribution is made. Thus, some of these costs will be apportioned by weight. Costs definitely not related to highway use, such as the costs of motor vehicle registration, legal costs, payments to related departments and agencies, etc. etc. etc., will be separated and charged in proportion to the number of vehicles registered. The remaining administrative costs, considered as contributing to construction and maintenance, will be distributed by relative use or vehicle miles.

#### The Secondary System

The argument and analysis which has been presented is based primarily on standards devised for the State Primary System. However, it can be shown that the same relative difference in accommodation is provided between corresponding volume classes on the Secondary System. Economy dictates that the geometrics of secondary highways be somewhat lower than the geometrics of primary highways, classification for classification. Structural standards are also slightly lower, because heavy vehicles do not make as much use of secondary facilities. The 200-400 VPD accommodation is still the "basic mean standard" and relates to repetitions of a 6k axle load. The 400-1000 VPD accommodation is the highest volume class of roadway to be constructed on this system, and relates to innumerable repetitions of a 10 K axle load. Axle loads larger than 10 K will be charged with the same responsibility, since vehicles imposing these loads do not use the system to the extent they use the Primary, and facilities are not specifically designed for their accommodation. Again, this produces the triangular distribution, lenient towards the heavy vehicle. Weight responsibility will be extended downwards to 2 K by the mathematics developed for the Primary System. Residual cost will be developed and distributed in the same way.





Structures, maintenance, and administration will be handled similarly. Table IV shows the design standards that the Automotive Safety Foundation have developed for the State Secondary System.

#### Federal Interstate System

Table II shows the design standards designated by the Automotive Safety Foundation for the Rural Interstate System. It will be noted that volume classifications are not used. However, the essential equivalence between standards selected for this system and those designated for roadways carrying more than 2000 VPD in the Primary System will be realized from comparison of Table II and Table III. Therefore, increments of weight cost developed for the Primary System will be employed in the distribution of cost of Interstate highways. The System will be handled separately, and separate mileage figures of vehicular use will be derived. Residual costs, structures, maintenance, and administration will be apportioned in the same manner as on the Primary System.

#### Local Rural Roads and City Streets

In a State where the motor-vehicle share of the cost of providing adequate highway facilities must be spread over relatively few domestic users, it is of paramount importance that the cost burden of local rural roads be distributed in a fair and equitable manner. The Montana Fact Finding Committee on Highways, Streets and Bridges is cooperatively engaged with the Montana Agricultural Experiment Station in a study to determine the relative benefits derived from highway development by users and other beneficiaries of highways. Together with this incremental analysis, the user portion of the cost of local rural roads will be allocated.

Although commercial vehicles use this system very little, these roads, nevertheless, generate the product that the commercial vehicle carries on Primary highways. However, the farmer, who is the main user, does realize a particular benefit from these facilities. There is a tie, in this respect, with the concept that the local rural road provides a large service to adjacent property. If the agencies studying the problem do find and recommend that the services rendered property is a substantial consideration in the apportionment of local rural road costs, and that property should be taxed accordingly, then the farmer may be considered to have been charged with his especial responsibility. The remaining cost of local rural roads would be reasonably apportioned equally to all vehicles registered in the State.

City streets will be studied separately. Some consideration will be given to zoning ordinances, and the type of enterprise a given street is intended to serve. This will affect the method used to distribute the motor vehicle user's share of the cost of these facilities. For example: In industrial zones where the street is built to service heavy vehicles, an incremental, (weight distribution), of cost would be in order. In commercial zones, an incremental distribution might be made to include the weight of axles of the heaviest vehicles



that commonly use the related streets. It does not appear that the incremental method should be applied to residential streets. A study is under way by the State Planning Survey, under the auspices of your Committee to develop the proportionate use of different classes of city streets. Where the incremental analysis is used, it is intended to apply the concepts and method developed in this report with appropriate modification.

### General

The advantages of the proposed method of incremental analysis, compared with other methods, may be enumerated as follows:

- (1) The number of considerations and assumptions is reduced to a minimum. The load-structure relationships on which the analysis is based are easily visualized, being related to actual construction.
- (2) No controversial definition of a basic vehicle or basic facility is necessary.
- (3) Once the premises are accepted as reasonable and just, it is impossible to prejudice the solution against any class of highway user.
- (4) The solution is valid until the whole pattern of highway needs is changed.
- (5) The proportionate responsibility developed is validly fitted to a program of "stage construction."
- (6) Structures may be "matched" to the facility they serve, and the same method of incremental distribution applied to them.
- (7) Maintenance costs may be related to facilities which will actually be constructed, and to prototypes which are now being maintained on the present highway system. A minimum of definition of benefits is involved, and no prejudice possible.
- (8) Some administrative cost may be distributed incrementally.

A pictorial outline of the methodology of the Montana solution is presented in Figure II. Although the problem is complex, and copious argument must be produced to describe and support the allotment of each element of cost to the motor vehicle user, it can be seen that the distribution itself is relatively simple. Once the premises of the solution are accepted as reasonable, little is left to an individual engineer's judgment. The analysis is completely without prejudice to any class of user on the highways. Careful consideration of the details discloses that where one of the premises apparently works to the disadvantage of a particular vehicle type, an offsetting advantage is produced





by another consideration. Equitability is achieved where exactness can not be determined. It is on this basis that support of the solution is solicited from all interested groups. Constructive criticism will be appreciated. No figures have, as yet, been applied to the method so that it is impossible to say what relative costs will result. All data necessary for the solution, however, has been secured by your Fact Finding Committee.

One additional problem remains to be considered as it relates to the incremental solution. This concerns the allotment of Federal-aid funds to the highway construction program. The form of analysis herein described takes no account of this source of revenue, in developing the scale of relative responsibility by which vehicles should be taxed. This is entirely as it should be. The relative responsibility of any vehicle group is not affected by the source of income which builds the highways. When the cost responsibility of the vehicle groups for a system is developed, and if moneys to build the system come from sources other than the motor-vehicle user, the whole curve of relative costs for that system should be adjusted accordingly. This may be accomplished by subtracting the "outside" income from the cost of the "basic" roadway structure in the system, which is apportioned to all vehicle groups on the same basis. Thus, the weight-responsibility curve is not destroyed. If the Federal Tax Structure obviously recovers moneys from given weight groups out of proportion to the defined responsibility, an adjustment can be made by subtracting the moneys so recovered from the amount this State would collect from the same weight groups, and "crediting" the lesser amount of Federal-aid to the cost of the "basic" structure.

This report is still in a preliminary stage. It is addressed to members of the Montana Fact Finding Committee on Highways, Streets, and Bridges; to members of the Incremental Advisory Committee; to the people of this State; and to all interested groups. Written comments should be addressed to Mr. Wm. L. Hall, Executive Director of the Montana Fact Finding Committee. The following are members of the Incremental Advisory Committee: Mr. Scott P. Hart, State Highway Engineer; Mr. Mort Flint, District Engineer, Bureau of Public Roads; and Dr. E. R. Dodge, Dean of Civil Engineering, Montana State College. The analysis has been prepared by Ralph D. Johnson, Research Engineer, Montana Highway Department, under advisement of the Incremental Advisory Committee.

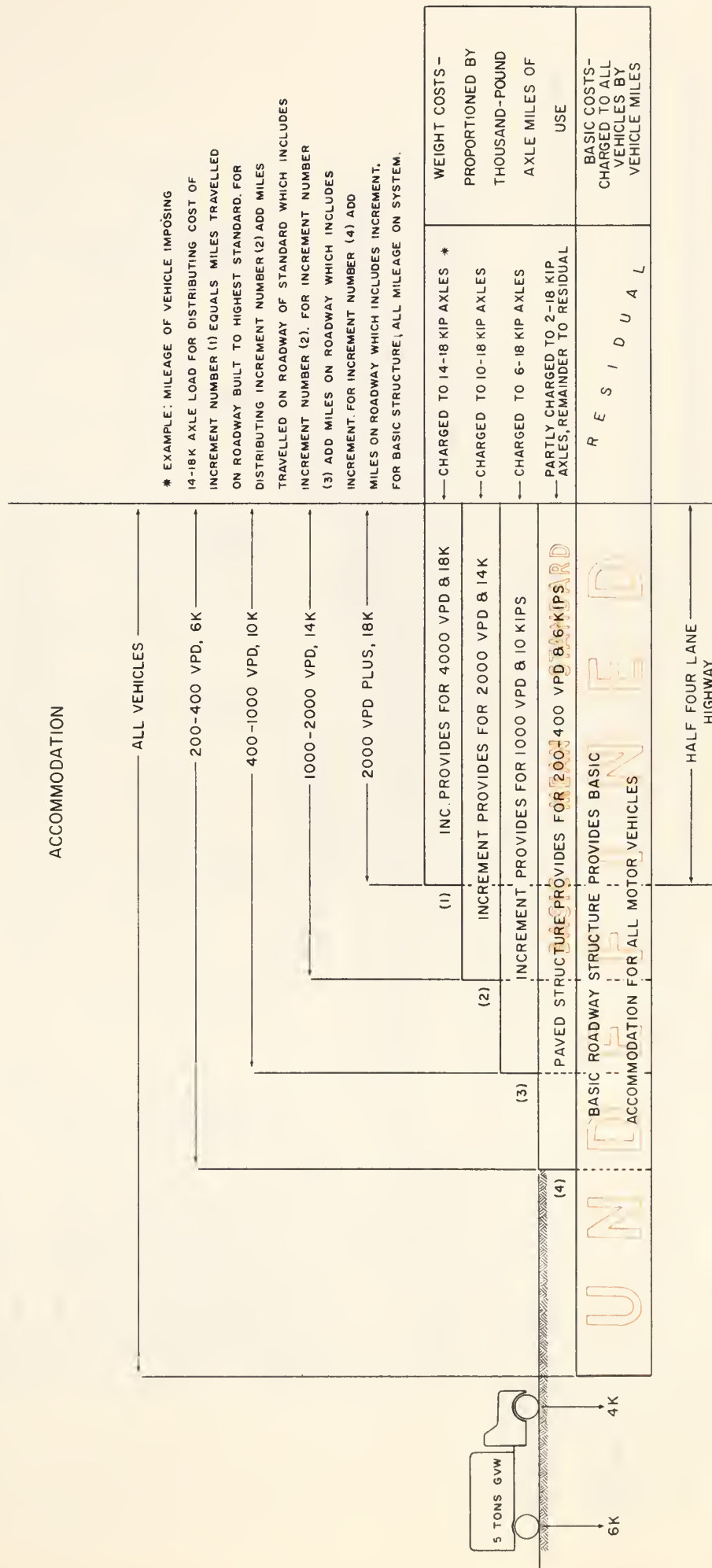


MONTANA FACT FINDING COMMITTEE  
ON  
HIGHWAYS, STREETS, AND BRIDGES

FIGURE II

# INCREMENTAL SOLUTION

DISTRIBUTION OF HIGHWAY COSTS TO MOTOR VEHICLE USERS  
ON  
PRIMARY AND INTERSTATE HIGHWAY SYSTEMS







MONTANA FACT FINDING COMMITTEE  
ON  
HIGHWAYS, STREETS, AND BRIDGES  
AUTOMOTIVE SAFETY FOUNDATION, CONSULTANTS

Table II

## DESIGN STANDARDS FOR RURAL INTERSTATE SYSTEM ROUTES

Terrain Class	Multi-Lane			2-Lane	
	Flat	Rolling	Mountain	Flat	Rolling
Design Speed — MPH	70	60	50	70	60
Operating Speed — MPH	50-55	45-50	40-45	50-55	45-50
Surface Type	Type I — High				
Lane Width — Feet	12				
Shoulder Width — Feet	10	8-10	① 4	10	8-10
Shoulder Type	Full Width-Bituminous Seal and Cover				
Maximum Curvature — Degree	3	5	7	3	5
Maximum Gradient — Percent	3	4	② 5	3	4
Stopping Sight Distance — Feet	700	525	400	700	525
③ Min. % Passing Sight Distance Available Per Mile	1500'	Not Applicable			
	800'				
④ Maximum Applicable 1976 DHV (Equivalent Sight Distance Passenger Vehicles)	100%				
	80%				
	60%				
	40%				
Minimum Median Width — Feet	⑤ 20	Not Applicable			
Minimum Right of Way Width — Ft.	200' Without Franchise Roads 300' With Franchise Roads			150' Without Franchise Roads 250' With Franchise Roads	
Control of Access	Required			⑥ Required 1956 DHV Exceeds 300. Partial Control of Access Permissible Where 1956 DHV is Less Than 300.	
⑦ Bridges	Loading Clearance Width — Feet Vertical Clearance — Feet			H 20 — S 16 Bridges 100 Ft. or Less in Length — Full Approach Roadway Width (Including Usable Shoulders). Bridges Over 100 Ft. in Length — Approach Pavement Width Plus 3 Foot Offset From Barrier Curbs.	
⑧ Railroad Separations	All Railroad Crossings			All Main Line Crossings With 2 or More Tracks All Single Track Main Line Crossings with 1956 DHV Over 200.	
Highway Separations	All Cross Roads and Places of Access			⑨	

- ① Wherever Feasible 8' Shoulders Should Be Provided in Mountainous Areas.
- ② Gradients in Rugged Terrain of 6 Percent, And in Unusual Conditions of 7 Percent, May Be Provided.
- ③ Passing Sight Distance in Mountainous and Heavy Rolling Topography Shall Be The Highest Obtainable With Reasonable Economy Capacity Analysis Will Determine Need For Truck Climbing Lanes.
- ④ Equivalent Passenger Car Capacities To Be Adjusted For Percent of Commercial Vehicles and Grades.
- ⑤ Median Width of 40 Feet Desirable.
- ⑥ For Partial Control of Access, Intersections at Grade (Public Roads and Private Drives) Shall Not Exceed Two Per Side Per Mile, 1956 ADT Shall Not Exceed 50, and Access Rights Between Such Intersections Are Acquired.
- ⑦ Standards Apply to Interstate Highway Bridges, Overpasses, and Underpasses. Standards For Crossroad Overpasses and Underpasses Shall Be Those for the Crossroad.
- ⑧ Appropriate Protective Devices Shall Be Provided at all Railroad Grade Crossings
- ⑨ All Cross Roads and Places of Access Where Full Control of Access is Required All Intersections With 1956 ADT of 50 or More on Sections Where Partial Control of Access is To Be Provided.



MONTANA FACT FINDING COMMITTEE  
ON  
HIGHWAYS, STREETS, AND BRIDGES  
AUTOMOTIVE SAFETY FOUNDATION, CONSULTANTS

**DESIGN STANDARDS FOR RURAL STATE HIGHWAYS**  
(OTHER THAN INTERSTATE SYSTEM ROUTES)

Table III

		Multi-Lane										2-Lane																			
1976 ADT		①					① Over 2000					1000 to 2000					400 to 1000					200 to 400					Under 200				
Terrain Class		Flat	Rolling	Mtn			Flat	Rolling	Mtn			Flat	Rolling	Mtn			Flat	Rolling	Mtn			Flat	Rolling	Mtn			Flat	Rolling	Mtn		
Design Speed — MPH		70	60	50			70	60	50			70	60	50			70	60	50			60	50	40			60	50	40		
Operating Speed — MPH		50-55	45-50	40-45			50-55	45-50	40-45			45-50	40-45	40-45			45-50	40-45	40-45			45-50	40-45	35-40			45-50	40-45	35-40		
Surface Type		Type 1-High										Type 2-Intermediate										Type 3-Low									
Lane Width — Feet		12																													
Shoulder Width — Feet		10	8-10	②4	10	8-10	②4	8	8	4	4	8	8	4	4	6	6	6	4	4	4	4	4	4	4	4	4	4	4		
Shoulder Type		Bituminous Seal and Cover										Gravel																			
Maximum Curvature — Degree		3	5	7	3	5	7	3	5	7	4	6	9	12	6	9	12	6	9	12	6	9	12	6	9	12	6	9	12		
③ Maximum Gradient — Percent		3	4	6	3	4	6	3	4	6	4	5	7	7	5	6	7	5	6	7	5	6	7	5	6	7	5	6	7		
③ Stopping Sight Distance — Ft		700	525	400	700	525	400	600	475	350	600	475	350	475	350	475	350	475	350	475	350	475	350	475	350	475	350	475	275		
③ Mn % Passing Sight Distance Available Per Mile		Not Applicable			10	10	-	10	10	-	10	10	-	10	Wherever Feasible																
④ Maximum 1976 DHV (Equivalent Passenger Vehicles)		1000	1200	1300	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane	Per Lane		
Min. Right of Way Width — Feet		⑤ 200' Without Frontage Rds 300' With Frontage Rds			150			100			Not Applicable																				
Bridges		⑥			H-20 — S-16			H-15 — S-12																							
Loading		16			30			28																							
Clearance Width — Feet		14			14			14																							
Vertical Clearance — Feet		14			14			14																							
⑦ Railroad Separations		All Main Line Crossings										On Main Line Crossings With 6 or More Trains Per Day or Exposure Factor of 10,000 or More										Not Required									

- Multi-Lane Highway Required Where a Two-Lane Highway Will Not Provide Capacity for 1976 ADT.
- Wherever Feasible 8' Shoulders Should Be Provided in Mountainous Areas on Highways Carrying Traffic in Excess of 2000 ADT
- Gradient and Sight Distance Standards for Volumes of Over 2000 ADT in Mountainous or Heavy Rolling Topography Shall Be the Highest Obtainable with Reasonable Economy Capacity Analysis Will Determine Need For Truck Climbing Lane on Two-Lane Roads.
- Equivalent Passenger Car Capacities To Be Adjusted for Percent of Trucks and Grades
- Portion Control of Access Required for All Multi-Lane Construction on New Location. Minimum Median Width of 20 Feet in Flat and Rolling Terrain and 4 Feet in Mountainous Terrain. Wider Median Widths Should Be Provided Wherever Feasible.
- Under 80 Feet in Length Full Approach Roadway Width. Over 80 Feet in Length Approach Roadway Where Exposure Factor (Trains Per Day X ADT) 3000.
- Appropriate Protective Devices Shall Be Provided at All Railroad Grade Crossings Where Exposure Factor (Trains Per Day X ADT) 3000.





MONTANA FACT FINDING COMMITTEE  
ON  
HIGHWAYS, STREETS, AND BRIDGES  
AUTOMOTIVE SAFETY FOUNDATION, CONSULTANTS

Table IV

## DESIGN STANDARDS FOR SECONDARY HIGHWAYS

1976 ADT	400 to 1000 ①			200 to 400			100 to 200			50 to 100			25 to 50			Under 25		
	Flat	Rolling	Mts	Flat	Rolling	Mts	Flat	Rolling	Mts	Flat	Rolling	Mts	Flat	Rolling	Mts	Flat	Rolling	Mts
Terrain Class																		
Design Speed - MPH	60	50	45	50	45	40	45	40	35	40	30	25	40	30	25	40	30	25
Surface Type	Type 2 Intermediate Bituminous			Type 3 Low Bituminous			Type 3 Law Bituminous			Type 4 Gravel - Heavy Course			Type 4 Gravel - Medium Course			Type 4 Gravel - Light Course		
Surface Width - Feet	24	24	24	24	24	22	24	24	22	24	24	22	22	22	20	20	20	20
Roadway Width - Feet	32	32	28	30	30	26	28	28	26	24	24	22	22	22	20	20	20	20
Maximum Curvature - Degree	5	7	10	7	10	12	10	12	17	12	22	40	12	22	40	12	22	40
Maximum Gradient - Per Cent	5	6	7	5	6	7	5	6	7	5	7	9	5	7	9	5	7	10
Stopping Sight Distance - Feet	475	350	315	350	315	275	315	275	240	275	200	165	275	200	165	275	200	165
Maximum Right of Way Width - Ft	120			100			100			66			66			66		
Bridges	Loading			H20-S16			H15-S12			H15			H10			H10		
	Clear Width - Feet			28			26			26	26	24	22	22	20	22	22	20
	Vertical Clearance - Ft			14			14			14			14			14		
Railroad Crossing Protection	Grade Separation When Exposure Factor Exceeds 10,000 - Flashing Lights When Exposure Factor Exceeds 3,000 ReflectORIZED Warning Signs At All Other Crossings - (Exposure Factor = 1976 ADT X Trains per Day)																	

① Use Design Standards for Rural State Highways When 1976 ADT Exceeds 1000

② In Built-up Suburban Areas Use Municipal Street Standards





